BANKURA UNIVERSITY

(West Bengal Act XIX of 2013- Bankura University Act, 2013)

Main Campus, Bankura Block-II, P.O.: Purandarpur, Dist.: Bankura, Pin- 722155, West Bengal

Office of the Secretary, Faculty Council for Undergraduate Studies

BKU/FCUG/184/2022 Date: 01/09/2022

NOTIFICATION

As directed, the undersigned is pleased to inform you that Bankura University has initiated the process to revise the existing CBCS syllabus of Undergraduate programme in Mathematics (Hons.) & Mathematics (Programme) and as an important corollary to the process, the workshop through online mode will be organized on the date mentioned herewith to get the feedback from the stakeholders. Present Students, Alumni, Guardians, Academicians and other stakeholders related to the specific programme are requested for their kind participation in the workshop and to present their views/ observations etc. The stakeholders may go through the draft syllabus attached herewith and convey their observations to the office of the undersigned on ugsecretaryoffice@bankurauniv.ac.in within seven days from the date of publication of notice.

Date: 07.09.2022

Time: 03:00 PM (IST)

Link to join: https://meet.google.com/deq-ercn-tjz

Sd/-
Secretary
Faculty Council for Undergraduate Studies

Syllabus of Mathematics (Hons.& Prog.)

Page nos are not tallied at present.

1. Introduction

The syllabus for Mathematics at undergraduate level using the Choice Based Credit system has been framed in compliance with model syllabus given by UGC.

The main objective of framing this new syllabus is to give the students a holistic understanding of the subject giving substantial weightage to both the core content and techniques used in Mathematics. Keeping in mind and in tune with the changing nature of the subject, adequate emphasis has been given on new techniques of mapping and understanding of the subject.

The syllabus has given equal importance to the three main branches of mathematics – Algebra, Calculus and Geometry.

The syllabus has also been framed in such a way that the basic skills of subject are taught to the students, and everyone might not need to go for higher studies and the scope of securing a job after graduation will increase.

It is essential that Mathematics students select their general electives courses from Physics, Chemistry and/or any branch of Life Sciences disciplines.

While the syllabus is incompliance with UGC model curriculum, some changes have been made to ensure all topics are covered and any of the subjects don't become difficult to be completed in one semester. For example, Core course 1 on "Calculus, Geometry & Vector Analysis" now also has introductory concepts on Geometry and Differential equations and has been renamed accordingly.

Similarly, Discipline Electives have been grouped where in student can choose 1 elective from a group of 3 papers. This has been done to help students learn a cross the semesters in their inter semesters.

Dissertation on any topic of Mathematics may be introduced instead of the 4^{th} Elective with accredit of 6 split into 2 + 4, where, 2 credits will be for continuous evaluation and 4 credits reserved for the merit of the dissertation.

2. Scheme for CBCS Curriculum for B.A./B.Sc.(Hons.) Mathematics

2.1 Credit Distribution

Course Type	Total Papers	Credits	
		Theory+Practical	Theory*
Core Courses	14	14*4=56 14*2=28	14*5=70 14*1=14
Discipline Specific Electives	4	4*4=16 4*2=8	4*5=20 4*1=4
Generic Electives/Interdisciplinary	4	4*4=16 4*2=8	4*5=20 4*1=4
Ability Enhancement Papers	2	2*4=8	2*4=8
Skill Enhancement Papers	2	2*4=8	2*4=8
Totals	26	148	148

*Tutorials of 1Credit will be conducted in case there is no practical component

2.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course–I	English Communication/Environmental Science	4
	Core course–I	Calculus, Geometry and Vector Analysis	6
	Core course–I Practical	-	-
	Core course–II	Algebra	6
	Core course–II Practical	-	-
	Genetic Elective–1	TBD	4
	Generic Elective–1 Practical	TBD	2
II	Ability Enhancement Compulsory Course–II	English Communication/Environmental Science	4
	Core course–III	Real Analysis	6
	Core course– III Practical	-	-
	Core course– IV	Group Theory-I	6
	Core course–IVPractical	-	-
	Generic Elective–2	TBD	4
	Generic Elective–2Practical	TBD	2
III	Core course–V	Theory of Real Functions	6
	Core course–V Practical	-	-
	Core course–VI	Ring Theory & Linear Algebra-I	6
	Core course–VI Practical	-	-
	Core course–VII	ODE & Multivariate Calculus -I	6
	Core course–VII Practical		
	Skill Enhancement Course–1	TBD	4

	Generic Elective–3	TBD	4
	Generic Elective–3 Practical	TBD	2
IV	Core course–VIII	Riemann Integration and Series of Functions	6
	Core course–VIII Practical	-	-
	Core course–IX	PDE & Multivariate Calculus-II	6
	Core course–IX Practical	-	-
	Core course –X	Mechanics	6
	Core course–X Practical	-	-
	Skill Enhancement Course-2	TBD	2
	Generic Elective–4	TBD	4
	Generic Elective–4 Practical	TBD	2
V	Core course– XI	Numerical Analysis	4
	Core course–XI Practical	Numerical Analysis Lab	2
	Core course–XII	Group Theory-II & Linear Algebra-II	6
	Core course–XII Practical	-	-
	Discipline Specific Elective–1	TBD	4
	Discipline Specific Elective– 1 Practical	TBD	2
	Discipline Specific Elective–2	TBD	4
	Discipline Specific Elective– 2 Practical	TBD	2
VI	Core course–XIII	Metric Spaces and Complex Analysis	6
	Core course–XIII Practical	-	-
	Core course–XIV	Probability and Statistics	6
	Core course–XIV Practical	-	-
	Discipline Specific Elective–3	TBD	4

	Discipline Specific Elective– 3 Practical	TBD	2
	Discipline Specific Elective–4	TBD	4
	DisciplineSpe cific Elective– 4 Practical	TBD	2

2.3 Choices for Discipline Specific Electives

Discipline SpecificElective–1	DisciplineSpecificElective–2	DisciplineSpecificElective–3	DisciplineSpecificElective–4
Linear Programming	Tensors and Differential Geometry	Advanced Algebra	Special Theory of Relativity
Mathematical Modelling	Advanced Mechanics	Discrete Mathematics	Number Theory
Integral Transforms and Fourier Analysis		Point Set Topology	Dissertation on Any Topic of Mathematics

- Optional Dissertation or project working place of one Discipline Specific Elective Paper(6 credits) in 6th Semester

2.4 Choices for Skill Enhancement Courses

Skill Enhancement Course-1	Skill Enhancement Course-2
Mathematical Logic	Graph Theory
Programming Using C	Operating System:Linux
	Programming Using C -Practical

3. Scheme for CBCS Curriculum for B.A./B.Sc. with Mathematics as a subject

3.1 Credit Distribution

Course Type	Total Papers	Credits	
		Theory+Practical	Theory*
Core Courses	4	4*4=16 4*2=8	4*5=20 4*1=4
Discipline Specific Electives	2	2*4=8 2*2=4	2*5=10 2*1=2
Ability Enhancement Papers	2	2*2=4	2*2=4
Skill Enhancement Papers	2	2*4=8	2*4=8
Totals	26	140	140

*Tutorials of 1Credit will be conducted in case there is no practical component

3.2 Scheme for CBCS Curriculum

Semester	Course Name	Course Detail	Credits
I	Ability Enhancement Compulsory Course–I	English Communication/Environmental Science	2
	Core course–I	Calculus, Geometry and Vector Analysis	6
	Core course–I Practical	-	-
II	Ability Enhancement Compulsory Course–II	English Communication/Environmental Science	2
	Core course–II	Algebra	6
	Core course– II Practical	-	-
III	Core course–III	Real Analysis	6
	Skill Enhancement Course–1	Graph Theory	4

	Skill Enhancement Course–1 Practical	-	-
IV	Core course–IV	ODE and Multivariate Calculus-I	6
	Core course–IV Practical	-	-
	Skill Enhancement Course-2	Mathematical Logic	4
	Skill Enhancement Course-2 Practical	-	-
V	Discipline Specific Elective–1	TBD	4
	Discipline Specific Elective– 1 Practical	TBD	2
	Skill Enhancement Course-3	Programming Using C	4
	Skill Enhancement Course-3 Practical	-	-
VI	Discipline Specific Elective–1	TBD	4
	Discipline Specific Elective– 1 Practical	TBD	2
	Skill Enhancement Course-4	Discrete Mathematics	4
	Skill Enhancement Course-4 Practical	-	-

3.3 Choices for Discipline Specific Electives

Discipline SpecificElective–1	DisciplineSpecificElective–2
Linear Programming	Number Theory
Mathematical Modelling	Probability and Statistics

3.4 Choices for Skill Enhancement Courses

Skill Enhancement Course-1	Skill Enhancement Course-2
Graph Theory	Mathematical Logic

Syllabus: B.A./B.Sc.(Hons) Mathematics

4. Core Subjects Syllabus : B.A./B.Sc.(Hons) Mathematics

4.1 Core T1–Calculus, Geometry & Vector Analysis

Calculus, Geometry & Vector Analysis	
	6 Credits
Unit 1	
Hyperbolic functions, higher order derivatives, Leibnitz rule and its applications to problems oftype eax+bsinx, eax+bcosx, (ax+b)nsinx, (ax+b)ncosx, concavity and inflection points, envelopes,asymptotes, curve tracing in Cartesian coordinates, tracing in polar coordinates of standardcurves,L'Hospital'srule,applicationsinbusiness,economicsandlifesciences.	
Unit 2	
Reduction formulae, derivations an dillustrations of reduction formulae of the type fsinnxdx, fcosnxdx, ftannxdx, fsecnxdx, f(logx)ndx, fsinnxsinmxdx, parametric equations, parameterizing a curve, arc length, arc length of parametric curves, area of surface of revolution. Techniques of sketching conics.	
Unit 3	
Reflection properties of conics, rotation of axes and second degree equations, classification of conics using the discriminant ,polar equations of conics. Spheres.Cylindrical surfaces. Central conicoids, paraboloids, plane sections of conicoids, Generating lines, classification of quadrics, Illustrations of graphing standard quadric surfaces like cone, ellipsoid.	
Unit 4	

Triple product, introduction to vector functions, operations with vector-valued functions, limits and continuity of vector functions, differentiation and integration of vector functions.

Graphical Demonstration (Teaching Aid)

1. Plotting of graphs of function eax+b,log(ax+b),1/(ax+b),sin(ax+b),cos(ax+b),|ax +b| and to illustrate the effect of a and b on the graph.
2. Plotting the graphs of polynomial of degree 4 and 5, the derivative graph, the second derivative graph and comparing them.
3. Sketching parametric curves (Eg. Trochoid, cycloid, epicycloids, hypocycloid).
4. Obtaining surface of revolution of curves.
5. Tracing of conics in Cartesian coordinates/polar coordinates.
6. Sketching ellipsoid, hyperboloid of one and two sheets, elliptic cone, elliptic, paraboloid, and hyperbolic paraboloid using Cartesian coordinates.

Reference Books

- G. B. Thomas and R. L. Finney,Calculus, 9th Ed.,PearsonEducation,Delhi,2005.
- M. J. Strauss, G. L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley(India)P. Ltd.(Pearson Education),Delhi,2007.
- H. Anton, I. Bivens and S. Davis, Calculus, 7th Ed., John Wiley and Sons(Asia) P.Ltd.,Singapore,2002.
- R.CourantandF.John,IntroductiontoCalculusandAnalysis(VolumesI&II),Springer-Verlag,NewYork,Inc.,1989.
- G. F. Simmons, Differential Equations, Tata McgrawHill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and Mathematical Analysis.
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata(India).
- M. R. Speigel, Schaum's Outline of Vector Analysis

4.2 Core T2-Algebra

Algebra	
	6 Credits
Unit 1	
Polar representation of complex numbers ,nth roots of unity, De Moivre's theorem for rational indices and its applications. Theory of equations: Relation between roots and coefficients, Transformation of equation, Descartes rule of signs, Sturm's theorem,Cubic and biquadratic equation. Inequality : The inequality involving AM≥GM≥HM, Cauchy-Schwartz inequality.	
Unit 2	
Equivalence relations, partial order relation, poset, linear order relation. Functions, Composition of functions, Invertible functions, One to one correspondence and cardinality of a set. Well-ordering property of positive integers, Division algorithm, Divisibility and Euclidean algorithm. Prime numbers and their properties, Euclid's theorem. Congruence relation between integers. Principles of Mathematical Induction, statement of Fundamental Theorem of Arithmetic.	
Unit 3	
Systems of linear equations, row reduction and echelon forms, vector equations, the matrix equation Ax=b, solution sets of linear systems, applications of linear systems, linear independence.	
Unit 4	
Introduction to linear transformations, matrix of a linear transformation, inverse of a matrix, characterizations of invertible matrices. Subspace of $\mathbb{R}^n$, dimension of subspaces of $\mathbb{R}^n$, Geometric significance of subspace. Rank of a matrix, Eigen values, Eigen Vectors and Characteristic Equation of a matrix. Cayley-Hamilton theorem and its use in finding the inverse of a matrix.	
Reference Books	
▸ Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006. ▸ Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education (Singapore) P. Ltd., Indian Reprint, 2005.	

- David C. Lay, Linear Algebra and its Applications, 3rd Ed., Pearson Education Asia, Indian Reprint, 2007.
- K. B. Dutta, Matrix and Linear Algebra.
- K.Hoffman, R.Kunze, Linear Algebra.
- W.S.Burnstine and A.W.Panton, Theory of Equations.

4.3 Core T3-Real Analysis

Real Analysis	
	6 Credits
Unit 1	
Review of Algebraic and Order Properties of R, Intervals, ε-neighbourhood of a point in R. Idea of countable sets, uncountable sets and uncountability of R. Bounded above sets, Bounded below sets, Bounded Sets, Unbounded sets. Suprema and Infima. Completeness Property of R and its equivalent properties. The Archimedean Property, Density of Rational (and Irrational) numbers in R, Limit points of a set, Isolated points, Interior points, Open set, closed set,the union and intersection on open and closed sets, derived set, Dense sets with examples, Illustrations of Bolzano-Weierstrass theorem for sets, compact sets in R, Heine-Borel Theorem.	
Unit 2	
Sequences,Bounded sequence, Convergent sequence, Limit of a sequence, uniqueness of limit, Limit Theorems. Sandwich rule. Nested interval theorem, Monotone Sequences, Monotone Convergence Theorem. Subsequences, lim inf, lim sup, A bounded sequence $\{x_n\}$ is convergent if and only if lim sup x_n= lim inf x_n. Divergence Criteria. Monotone Subsequence Theorem (statement only), Bolzano Weierstrass Theorem for Sequences. Cauchy sequence, Cauchy's Convergence Criterion. Cauchy's first and second limit theorems with applications.	
Unit 3	
Infinite series, convergence and divergence of infinite series, Cauchy Criterion, Tests for convergence: Comparison test, Limit Comparison test, Ratio Test, Cauchy's nth root test, Integral test, Gauss test (statements only) Alternating series, Leibniztest. Absolute and Conditional convergence.	
Graphical Demonstration(Teaching Aid)	

1. Plotting of recursive sequences.
2. Study the convergence of sequences through plotting.
3. Verify Bolzano-Weierstrass theorem through plotting of sequences and hence identify convergent subsequences from the plot.
4. Study the convergence/divergence of infinite series by plotting their sequences of partial sum.
5. Cauchy's root test by plotting nth roots.
6. Ratio test by plotting the ratio of nth and (n+1)th term.

Reference Books

- R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons(Asia)Pvt.Ltd.,Singapore,2002.
- Gerald G.Bilodeau, Paul R.Thie, G. E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
- Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, A First Course in Real Analysis, Springer Verlag, NewYork,1994.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, VolI, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis I, Hindustan Book Agency, 2006
- S. Goldberg, Calculus and Mathematical Analysis.

4.4 Core T4-Group Theory-I

Group Theory-I	
	6 Credits
Unit 1	
Symmetries of a square, definition of group, examples of groups including permutation groups, Dihedral groups and Quaternion groups (through matrices), elementary properties of groups, examples of commutative and non-commutative groups. order of an element, order of a group. Subgroups and examples of subgroups, necessary and sufficient condition for a nonempty subset of a group to be a subgroup. Normalizer, centralizer, center of a group, product oftwo subgroups.	
Unit 2	
Properties of cyclic groups, classification of subgroups of cyclic groups. Cycle notation forpermutations, properties of permutations, even and odd permutations, alternating group, properties of cosets, Lagrange's theorem and consequences including Fermat's Little theorem.	
Unit 3	
External direct product of a finite number of groups, normal subgroups, factor groups, Cauchy's theorem for finite abelian groups.	
Unit 4	
Group homomorphisms, properties of homomorphisms, correspondence theorem and one-one correspondence between the set of all normal subgroups of a group and the set of all congruences on that group, Cayley's theorem, properties of isomorphisms. First, Second and Third isomorphism theorems.	
Reference Books	

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
- Dummit, Foote.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- Joseph J. Rotman, An Introduction to the Theory of Groups, 4th Ed., 1995.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India,1975.
- D. S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra.

4.5 Core T5–Theory of Real Functions

Theory of Real Functions	
	6 Credits
Unit1	
Limits of functions (ε - δ approach), algebra of limits of functions, sequential criterion for limits, divergence criteria. Limit theorems, one sided limits. Infinite limits and limits at infinity. Continuous functions, sequential criterion for continuity and discontinuity. Algebra of continuous functions. Continuous functions on an interval, intermediate value theorem, location of roots theorem, preservation of intervals theorem. Uniform continuity, non-uniform continuity criteria, uniform continuity theorem. Discontinuity of functions, different types of discontinuity, step functions, piecewise discontinuity, monotone functions, Theorems: a monotone function have only jump discontinuity and at most countably many points of discontinuity Neighbourhood properties of continuous functions on boundedness and maintenance of sign, continuous function on a bounded closed interval attains its bound.	
Unit2	
Differentiability of a function at a point and in an interval, Caratheodory's theorem, algebra of differentiable functions. Meaning of sign of derivatives, Chain rule, Lipschitz condition and associate result on derivative, Relative extrema, interior extremum theorem. Rolle's theorem. Mean value theorems: Lagranges, Cauchy's, intermediate value property of derivatives, Darboux's theorem. Applications of mean value theorems to inequalities and approximation of polynomials.	
Unit3	
Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, concept of convex functions with examples, application of Taylor's theorem to convex functions, relative extrema. Taylor's series and Maclaurin's series expansions of exponential and trigonometric functions, ln(1 + x), 1/ax+b and $(1+x)^n$ with their range of validity, Applications of Taylor's theorem to inequalities. Statement of L'Hospital's rule, and its associated results, point of local extremum of a function on an interval (ensure to include the concepts of interval in calculus part of C-1: Calculus, geometry and differential equations), Sufficient condition for the existence of a local	

extremum of a function (statement only), determination of local extremum using first order derivative, applications of the principle of maximum/minimum.

Reference Books

- R. Bartle and D. R. Sherbert, Introduction to Real Analysis, John Wiley and Sons,2003.
- K. A. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.

- A. Mattuck, Introduction to Analysis,Prentice Hall,1999.
- S. R. Ghorpade and B.V.Limaye, A Course in Calculus and Real Analysis, Springer, 2006.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis,Tata McGraw-Hill
- Terence Tao, Analysis II, Hindustan Book Agency, 2006

4.6 Core T6-Ring Theory and Linear Algebra-I

Ring Theory and Linear Algebra-I	
	6 Credits
Unit 1	
Definition and examples of rings, properties of rings, subrings, polynomial rings, integral domains and fields,subfield, necessary and sufficient condition for a nonempty subset of a field to be a subfield, characteristic of a ring. Ideal, ideal generated by a subset of a ring, factor rings, operations on ideals, prime and maximal ideals.	
Unit2	
Ringhomomorphisms, properties of ringhomomorphisms. Isomorphism theorems I, II and III, Correspondence theorem, congruence on rings, one-one correspondence between the set of ideals and the set of all congruences on a ring.	
Unit 3	
Vectorspaces, subspaces, algebra of subspaces, quotient spaces, linear combination of vectors, linear span, linear independence, basis and dimension, dimension of subspaces.	
Unit 4	
Linear transformations, null space, range, rank and nullity of a linear transformation, matrix representation of a linear transformation, change of coordinate matrix. Algebra of linear transformations. Isomorphisms. Isomorphism theorems, invertibility and isomorphisms. Inner product spaces, matrix of an inner product, Cauchy-Schwarz inequality. orthogonal/orthonormal set, Orthonormal basis, Gram-Schmidt orthogonalisation process. Matrix of a linear operator on finite dimensional inner product spaces w.r.t orthogonal (orthonormal) basis. Inner product space isomorphism and related theorems.	
Reference Books	
▸ John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002. ▸ M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011. ▸ Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004. ▸ Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., Narosa Publishing House, New Delhi, 1999. ▸ S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.	

- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- A Geometric Approach, Prentice Hall of India, 1999.

4.7 Core T7–ODE & Multivariate Calculus-I

ODE & Multivariate Calculus-I	
	6 Credits
Unit 1	
First order differential equations: Exact differential equations and integrating factors, special integrating factors and transformations, linear equations and Bernoulli equations, the existence and uniqueness theorem of Picard (Statement only).	
Unit 2	
Linear equations and equations reducible to linear form. First order higher degree equations solvable for *x, y* and *p*. Clairaut's equations and singular solution.	
Unit 3	
Basic Theory of linear systems in normal form, homogeneous linear systems with constant coefficients: Two Equations in two unknown functions.	
Unit 4	
Linear differential equations of second order, Wronskian: its properties and applications, Euler equation, method of undetermined coefficients, method of variation of parameters.	
Unit 5	
System of linear differential equations, types of linear systems, differential operators, an operator method for linear systems with constant coefficients.	
Unit 6	
Planar linear autonomous systems : Equilibrium (critical) points, Interpretation of the phase plane and phase portraits.	

Unit 7

Power series solution of a differential equation about an ordinary point, solution about a regular singular point (up to second order).

Unit 8

Concept of neighbourhood of a point in $R^n(n > 1)$, interior point, limit point, open set and closed set in $R^n(n > 1)$.

Unit 9

Functions from $R^n(n > 1)$ to $R^m(m \geq 1)$, limit and continuity of real-valued functions of two or more variables. Partial derivatives, total derivative and differentiability, sufficient condition for differentiability. Chain rule for one and two independent parameters, theorems on equality of mixed partial derivatives of two variables, directional derivatives, the gradient, maximal and normal property of the gradient, tangent planes. Extrema of functions of two and three variables, method of Lagrange multipliers, constrained optimization problems.

Reference Books

- D.A. Murray, Introductory course in Differential Equations, Orient and Longman
- H.T. H. Piaggio, Elementary Treaties on Differential Equations and their applications, C.B.S Publisher & Distributors, Delhi, 1985.
- G. F. Simmons, Differential Equations, Tata Mc Graw Hill
- S. L. Ross, Differential Equations, 3rd Ed., John Wiley and Sons, India, 2004.
- M. R. Speigel, Schaum's outline of Laplace Transform
- Horst R. Beyer, Calculus and Analysis, Wiley, 2010.

4.8 Core T8– Riemann Integration and Series of Functions

Riemann Integration and Series of Functions	
	6 Credits

Group A: Riemann Integration

Unit 1

Riemann integration: Partition and refinement of a partition, results related to them, inequalities of upper and lower sums, Darboux integration, Darboux theorem, Riemann conditions of integrability, Riemann sum and definition of Riemann integral through Riemann sums, equivalence of two Definitions. Necessary and sufficient condition for Riemann integrability

Integrability of sum, scalar multiple, product, quotient, modulus of Riemann integrable functions.

Riemann integrability of monotone and continuous functions, Properties of the Riemann integral; definition and integrability of piecewise continuous and monotone functions. Zero set, Examples of zero sets, Theorem: a bounded function on a closed and bounded interval in Riemann integrable if and only if the set of points of discontinuity is a zero set.

Functions defined by $\int_a^x f(t)dt$, its properties, primitive, logarithmic and exponential functions, their properties

Intermediate Value theorem for Integrals. Fundamental theorem of Integral Calculus.

Unit 2

Improper integrals. Range of integration: finite or infinite, types of improper integration, Necessary and sufficient condition for convergence of improper integral for both cases, Test of convergence: comparison test, M-test, absolute and non-absolute convergence and inter-relations, Statement of Abel's and Dirichlet's test on the integral of product.

Convergence of Beta and Gamma functions. Their properties and inter-relation $[\Gamma(n)\Gamma(1-n) = \frac{\pi}{sinn\pi}$, Evalution: $\int_0^{\frac{\pi}{2}} sin^n x dx$, $\int_0^{\frac{\pi}{2}} cos^n x dx$, $\int_0^{\frac{\pi}{2}} tan^n x dx$ by Beta and Gamma functions.

Group B: Series of Functions

Unit 3

Pointwise and uniform convergence of sequence of functions. Theorems on continuity, derivability and integrability of the limit function of a sequence of functions. Series of functions.

Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.

Unit 4

Fourier series: Definition of Fourier coefficients and series, Reimann Lebesgue lemma, Bessel's inequality, Parseval's identity, Dirichlet's condition.

Examples of Fourier expansions and summation results for series.

Unit 5

Powerseries, radius of convergence, Cauchy Hadamard Theorem.

Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.

Reference Books

- K.A.Ross, Elementary Analysis, The Theory of Calculus, Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004.
- R. G. Bartle D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons(Asia) Pvt.Ltd., Singapore,2002.
- Charles G. Denlinger, Elements of Real Analysis, Jones & Bartlett (Student Edition), 2011.
- S. Goldberg, Calculus and Mathematical Analysis.
- Santi Narayan, Integral Calculus.
- T. Apostol, Calculus I,II.

4.9 Core T9-PDE & Multivariate Calculus-II

PDE & Multivariate Calculus-II	
	6 Credits
Unit 1	
Partial differential equations of the first order, Lagrange's solution, non linear first order partial differential equations, Charpit's general method of solution, some special types of equations which can be solved easily by methods other than the general method.	
Unit 2	
Derivation of heat equation, wave equation and Laplace equation. Classification of second order linear equations as hyperbolic, parabolic or elliptic. Reduction of second order linear equations to canonical forms.	
Unit3	
The Cauchy problem, Cauchy-Kowalewskaya theorem, Cauchy problem of finite and infinite string. Initial boundary value problems. Semi-infinite string with a fixed end, semi-infinite string with a free end. Equations with non-homogeneous boundary conditions. Non-homogeneous wave equation. Method of separation of variables, solving the vibrating string problem. Solving the heat conduction problem.	
Unit4	
Multiple integral: Concept of upper sum, lower sum, upper integral, lower-integral and double integral (no rigorous treatment is needed). Statement of existence theorem for continuous functions. Iterated or repeated integral, change of order of integration. Triple integral. Cylindrical and spherical coordinates. Change of variables in double integrals and triple integrals. Transformation of double and triple integrals (problems only). Determination of volume and surface area by multiple integrals (problems only). Differentiation under the integral sign, Leibniz's rule (problems only).	
Unit5	
Definition of vector field, divergence and curl. Line integrals, applications of line integrals : mass and work. Fundamental theorem for line integrals, conservative vector fields, independence of path.	
Unit 6	
Green's theorem, surface integrals, integrals over parametrically defined surfaces. Stoke's theorem, The Divergence theorem.	
Reference Books	

- G.B. Thomas and R.L. Finney, Calculus, 9th Ed., Pearson Education, Delhi, 2005.
- M.J. Strauss, G.L. Bradley and K. J. Smith, Calculus, 3rd Ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
- E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer (SIE), 2005.
- James Stewart, Multivariable Calculus, Concepts and Contexts, 2nd Ed., Brooks /Cole, Thomson Learning, USA, 2001
- T. Apostol, Mathematical Analysis, Narosa Publishing House.
- Courant and John, Introduction to Calculus and Analysis, Vol II, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill.
- Horst R. Beyer, Calculus and Analysis, Wiley, 2010.
- Ian Sneddon, Elements of Partial Differential Equations, McGraw-Hill International Edition, 1957.
- M.D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand Higher Academic, 19th Edition, 2017.
- K.Sankara Rao, Introduction to Partial Differential Equations, PHI, Third Edition, 2015.

4.10 Core T10–Mechanics

Mechanics	
	6 Credits
Unit 1	
Equilibrium of a particle, Equilibrium of a system of particles, Necessary conditions of equilibrium, Moment of a force about a point, Moment of a force about a line, Couples, Moment of a couple, Equipollent system of forces, Work and potential energy, Principle of virtual work for a system of coplanar forces acting on a particle or at different points of a rigid body, Forces which can be omitted in forming the equations of virtual work.	
Unit 2	
Centres of gravity of plane area including a uniform thin straight rod, triangle, circular arc, semicircular area and quadrant of a circle, Centre of gravity of a plane area bounded by a curve, Centre of gravity of a volume of revolution; Flexible strings, Common catenary, Intrinsic and Cartesian equations of the common catenary, Approximations of the catenary.	
Unit 3	
Simple harmonic motion (SHM) and its geometrical representation, SHM under elastic forces, Motion under inverse square law, Motion in resisting media, Concept of terminal velocity, Motion of varying mass.	
Unit 4	
Kinematics and kinetics of the motion, Expressions for velocity and acceleration in Cartesian, polar and intrinsic coordinates; Motion in a vertical circle, projectiles in a vertical plane and cycloidal motion.	
Unit 5	
Equation of motion under a central force, Differential equation of the orbit, (p, r) equation of the orbit, Apses and apsidal distances, Areal velocity, Characteristics of central orbits, Kepler's laws of planetary motion.	

- I.H.Shames and G.KrishnaMohan Rao, Engineering Mechanics: Statics and Dynamics, (4thEd.), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- R.C.Hibbeler and Ashok Gupta, Engineering Mechanics:Statics and Dynamics,11thEd., Dorling Kindersley(India) Pvt. Ltd.(Pearson Education), Delhi.
- Chorlton, F., Textbook of Dynamics.
- Loney,S.L., An Elementary Treatise on the Dynamics of particle and of Rigid Bodies
- Loney, S.L., Elements of Statics and Dynamics I and II.
- Ghosh,M.C, Analytical Statics.
- Verma,R.S., A Text book on Statics, Pothishala,1962.
- Matiur Rahman, Md., Statics.

Ramsey,A.S., Dynamics (PartI).

P. L. Srivatava (1964). *Elementary Dynamics*. Ram Narin Lal, Beni Prasad Publishers Allahabad.

J. L. Synge & B. A. Griffith (1949). *Principles of Mechanics*. McGraw-Hill.

A. S. Ramsey (2009). *Statics*. Cambridge University Press.

A. S. Ramsey (2009). *Dynamics*. Cambridge University Press.

4.11 Core T11-Numerical Analysis

Numerical Analysis	
	4 Credits
Unit 1	
Round-off error and computer arithmetic, Local and global truncation errors, Algorithms and convergence; Bisection method, False position method, Fixed point iteration method, Newton's method and secant method for solving equations.	
Unit 2	
Partial and scaled partial pivoting, Lower and upper triangular (LU) decomposition of a matrix and its applications, Thomas method for tridiagonal systems; Gauss-Jacobi, Gauss-Seidel and successive over-relaxation (SOR) methods.	
Unit 3	
Lagrange and Newton interpolations, Piecewise linear interpolation, Cubic spline interpolation, Finite difference operators, Gregory-Newton forward and backward difference interpolations.	
Unit 4	

First order and higher order approximation for first derivative, Approximation for second derivative; Numerical integration: Trapezoidal rule, Simpson's rules and error analysis,

Bulirsch-Stoer extrapolation methods, Richardson extrapolation.

Unit 5

Euler's method, Runge-Kutta methods, Higher order one step method, Multi-step methods; Finite difference method, Shooting method, Real life examples: Google search engine, 1D and 2D simulations, Weather forecasting.

Reference Books

- Brian Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
- M.K.Jain, S.R.K.Iyengar and R.K.Jain, Numerical Methods for Scientific and Engineering Computation, 6th Ed., New age International Publisher, India, 2007.
- C.F.GeraldandP.O.Wheatley,AppliedNumericalAnalysis,PearsonEducation,India,2008.
- Uri M.Ascher and Chen Greif, A First Course in Numerical Methods, 7th Ed., PHI Learning Private Limited, 2013.
- John H.Mathews and Kurtis D. Fink, Numerical Methods Using Matlab, 4th Ed., PHI Learning Private Limited, 2012.
- Scarborough, James B., Numerical Mathematical Analysis, Oxford and IBH publishing co.
- Atkinson, K. E., An Introduction to Numerical Analysis,
- F. B. Hildebrand (2013). *Introduction to Numerical Analysis*: (2nd edition). Dover Publications.

Robert J. Schilling & Sandra L. Harris (1999). *Applied Numerical Methods for Engineers Using* MATLAB *and C*. Thomson-Brooks/Cole.

4.12 CoreT11- Numerical Analysis Lab

Numerical Analysis	
	2 Credits

List of practical (using any software)

1. Calculate the sum 1/1+1/2+1/3+1/4+----------+1/N.
2. Enter 100 integers into an array and sort the min an ascending order.
3. Solution of transcendental and algebraic equations by
    a. Bisection method
    b. Newton Raphson method.
    c. Secant method.
    d. Regula Falsi method.
4. Solution of system of linear equations
    a. LU decomposition method
    b. Gaussian elimination method
    c. Gauss-Jacobi method
    d. Gauss-Seidel method
5. Interpolation
    a. Lagrange Interpolation
    b. Newton Interpolation
6. Numerical Integration
    a. Trapezoidal Rule
    b. Simpson's one third rule
    c. Weddle's Rule
    d. Gauss Quadrature
7. Method of finding Eigenvalue by Power method
8. Fitting a Polynomial Function
9. Solution of ordinary differential equations
    a. Euler method
    b. Modified Euler method
    c. Runge-Kutta method

Note: For any of the CAS(Computer aided software)Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

4.13 Core T12–Group Theory-II & Linear Algebra II

Group Theory-II & Linear Algebra II	
	6 Credits
Unit1	
Automorphism, innerautomorphism, automorphismgroups, automorphism groups of finite and infinite cyclic groups, applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.	
Unit 2	
Properties of external direct products, the group of units modulonasan external direct product, internal direct products, Fundamental Theorem of finitely generated abelian groups, invariant factors, elementary divisors.	
Unit 3	
Group action (definition, examples), orbit formulas, Class equation and consequences, conjugacy in S_n, p-groups, Cauchy's theorem.	
Unit 4	
Dual spaces, dual basis, double dual, transpose of a linear transformation and its matrix in the dual basis, annihilators. Eigen spaces of a linear operator, diagonalizability, invariant subspaces and Cayley-Hamilton theorem, Project on operator and its relation with the eigen values of a linear operator, the minimal polynomial for a linear operator, primary decomposition theorem, invariant factors, elementary divisors, working procedure to find possible Rational and Jordan canonical forms of a linear operator.	
Unit 5	
The adjoint of a linear operator. Normal and self-adjoint operators. Bessel's inequality, Orthogonal complement, Orthogonal projections, Best approximation and itsapplication to Least Squares approximation, minimal solutions to systems of linear equations. Bilinear and quadratic forms, Diagonalisation of symmetric matrices, Second derivative test for	

critical point of a function of several variables, Hessian matrix, Sylvester's law of inertia. Index, signature.

Reference Books

- John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson,2002.
- M. Artin, Abstract Algebra, 2nd Ed., Pearson,2011.
- Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999.
- David S. Dummit and Richard M. Foote, Abstract Algebra, 3rd Ed., John Wiley and Sons (Asia) Pvt. Ltd., Singapore, 2004.
- J. R. Durbin, Modern Algebra, John Wiley & Sons, New York Inc., 2000.
- D. A. R. Wallace, Groups, Rings and Fields, Springer Verlag London Ltd., 1998
- D. S. Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra.
- I. N. Herstein, Topics in Algebra, Wiley Eastern Limited, India, 1975.
- Stephen H. Friedberg, Arnold J. Insel, Lawrence E. Spence, Linear Algebra, 4th Ed., Prentice-Hall of India Pvt. Ltd., New Delhi, 2004.
- S. Lang, Introduction to Linear Algebra, 2nd Ed., Springer, 2005.
- Gilbert Strang, Linear Algebra and its Applications, Thomson, 2007.
- S. Kumaresan, Linear Algebra- AGeometric Approach, Prentice Hall of India, 1999.
- Kenneth Hoffman, RayAlden Kunze, Linear Algebra, 2nd Ed., Prentice-Hall of India Pvt. Ltd., 1971.

4.14 Core T13-Metric Spaces and Complex Analysis

Metric Spaces and Complex Analysis	
	6 Credits

Group A : Metric Spaces

Unit1

Metrics paces: Definition and examples. Open and closed balls, neighbourhood, open set, interior of a set. Limit point of a set, closed set, closed set as a complement of an open set, diameter of a set, distance of a set from a point, distance between two sets, subspaces, dense sets, separable spaces.

Sequences in metric spaces, Cauchy sequences. Complete Metric Spaces with examples, Examples of incomplete metric spaces, every convergent sequence is Cauchy and bounded but converse need not be true, Cantor's intersection theorem.

Unit 2

Continuous mappings, sequential criterion and other characterizations of continuity.Uniform continuity. Connectedness, connected subsets of R.

Compactness: Concept of compactness, Sequential compactness, Heine Borel property, Totally bounded spaces,finite intersection property, and continuous functions on compact ~~sets~~ spaces.

Homeomorphism. Contraction mappings. Banach Fixed point Theorem and its application to ordinary differential equation.

Group B: Complex Analysis

Unit 3

Limits, Limits involving the point at infinity, continuity. Properties of complex numbers, regions in the complex plane, functions of complex variable, mappings.

Derivatives, differentiation formulas, Cauchy-Riemannequations, sufficient conditions for differentiability.

Unit 4

Analytic functions, examples of analytic functions, exponential function, Logarithmic function, trigonometric function, derivatives of functions, and definite integrals of functions. Contours, Contour integrals and its examples, upper bounds for moduli of contour integrals.

Cauchy- Goursat theorem, Cauchy integral formula.

Unit 5

Liouville's theorem and the fundamental theorem of algebra. Convergence of sequences and series, Taylor's series and its applications.

Unit 6

Laurent's series and its applications, absolute and uniform convergence of power series.

Reference Books

- Satish Shirali and Harikishan L.Vasudeva, Metric Spaces, Springer Verlag, London, 2006.
- S. Kumaresan, Topology of Metric Spaces, 2ndEd., Narosa Publishing House, 2011.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 2004.
- James Ward Brown and Ruel V.Churchill, Complex Variablesand Applications, 8thEd., McGraw–Hill International Edition, 2009.
- Joseph Bak and Donald J.Newman, ComplexAnalysis, 2ndEd., Undergraduate Texts in Mathematics,Springer-VerlagNewYork,Inc.,NewYork,1997.
- S. Ponnusamy, Foundations of complex analysis.
- E. M. Stein and R.Shakrachi, Complex Analysis, Princeton University Press.

4.15 Core T14- Probability and Statistics

Probability and Statistics	
	6 Credits

Unit 1

Random experiment, Outcome, Event, Mutually Exclusive Events,Equally likely and Exhaustive. Classical definition of probability, Theorems of Total Probability, Conditional, probability and Statistical Independence. probability axioms, real random variables (discrete and continuous), cumulative distribution function, probability mass/density functions, mathematical expectation, moments, moment generating function, characteristic function, discrete distributions: uniform, binomial, Poisson, geometric, negative binomial, continuous distributions: uniform, normal, exponential.

Unit 2

Joint cumulative distribution function and its properties, joint probability density functions, marginal and conditional distributions, expectation of function of two random variables, conditional expectations, independent random variables, bivariate normal distribution, correlation coefficient, joint moment generating function (jmgf) and calculation of covariance (from jmgf), linear regression for two variables.

Unit 3

Markov and Chebyshev's inequality, statement and interpretation of(weak) law of large numbers and strong law of large numbers. Central Limit theorem for independent and identically distributed random variables with finite variance, Markov Chains, Chapman-Kolmogorov equations, classification of states.

Unit 4

Random Samples, Sampling Distributions, Estimation of parameters, Testing of hypothesis, Sampling from the normal distributions, Chi-square, *t* and *F*-distributions.

Reference Books

- Robert V.Hogg, Joseph W. Mc Kean and Allen T.Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007.
- Irwin Miller and Marylees Miller, John E.Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006.
- Sheldon Ross, Introduction to Probability Models, 9th Ed., Academic Press, Indian Reprint, 2007.
- Alexander M. Mood, Franklin A.Graybill and Duane C.Boes, Introduction to the Theory of Statistics,3rd Ed.,Tata McGraw-Hill, Reprint 2007.
- A. Gupta, Ground work of Mathematical Probability and Statistics, Academic publishers.

5. Department Specific Electives Subjects Syllabus

5.1 DSET1-Linear Programming

Linear Programming	
	6 Credits
Unit 1	
Introduction to linear programming problem. Theory of simplex method, graphical solution, convex sets, optimality and unboundedness, the simplex algorithm, simplex method in tableau format, introduction to artificial variables, two-phase method. Big-M method and their comparison.	
Unit 2	
Duality, formulation of the dual problem, primal-dual relationships, economic interpretation of the dual. Transportation problem and its mathematical formulation, northwest-corner method, least cost method and Vogel approximation method for determination of starting basic solution, algorithm for solving transportation problem, assignment problem and its mathematical formulation, Hungarian method for solving assignment problem.	
Unit 3	
Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies, graphical solution procedure, linear programming solution of games.	
Reference Books	
▸ Mokhtar S. Bazaraa, John J. Jarvis and Hanif D. Sherali, Linear Programming and Network Flows, 2nd Ed., John Wiley and Sons, India, 2004. ▸ F.S. Hillier and G.J. Lieberman, Introduction to Operations Research, 9th Ed., Tata McGraw Hill, Singapore,2009. ▸ Hamdy A. Taha, Operations Research, An Introduction, 8th Ed., Prentice-Hall India, 2006. ▸ G. Hadley, Linear Programming, Narosa Publishing House, New Delhi, 2002.	

5.2 DSET2-Mathematical Modeling

Mathematical Modeling	
	6 Credits
Unit 1	
Introduction, Emergence of Mathematical Modelling on simple situations; Basic steps of Mathematical Modelling - its needs; Process / technique of Mathematical Modeling; Some characteristics of Mathematical Models; Importance of the usage of mathematical models over physical models; Classification of mathematical models; Deterministic and Stochastic models and their distinctive features with illustrations; Limitations of Mathematical Modelling.	
Unit 2	
Autonomous dynamical system and its classification, Jacobian matrix, System reducible to autonomous system, Time-dependent system, Fixed points and their characterization – node, saddle point, focus, centre and concept of limit cycle with simple illustrations, Stability of fixed points.	
Unit 3	
Modelling of Physical Systems: Formulation of some mathematical models and their analyses for (i) harmonic oscillator, (ii) damped and forced oscillator. Simple pendulum; Compound pendulum; Electric circuits (L-R, R-C, L-R-C).	
Unit 4	
Biological System: Population Models: (i) Single-species models – Exponential, Logistic and Gompertz growth models; Stochastic birth and death processes; Discrete-time models. (ii) Interacting populations – A classical predator-prey model; Stability of equilibrium positions; Derivation of Lotka-Volterra model; Two competing species model and its stability analysis; Mutualism model and its stability. Harvest models and optimal control theory.	
Reference Books	
▸ Tyn Myint-U and Lokenath Debnath, Linear Partial Differential Equation for Scientists and Engineers, Springer, Indian reprint, 2006. ▸ Strogatz, Steven H. Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering. CRC press, 2018.	

- Kot, Mark. Elements of mathematical ecology. Cambridge University Press, 2001.
- FrankR.Giordano,MauriceD.WeirandWilliamP.Fox,AFirstCourseinMathematical
- Modeling, Thomson Learning, London and New York, 2003.

5.3 DSET3–Integral Transforms and Fourier Analysis

Integral Transforms and Fourier Analysis	
	6 Credits
Unit 1	
Laplace transform, Linearity, Existence theorem, Laplace transforms of derivatives and integrals, Shifting theorems, Change of scale property, Laplace transforms of periodic functions, Dirac's delta function.	
Unit 2	
Differentiation and integration of transforms, Convolution theorem, Integral equations, Inverse Laplace transform, Lerch's theorem, Linearity property of inverse Laplace transform, Translations theorems of inverse Laplace transform, Inverse transform of derivatives, Applications of Laplace transform in obtaining solutions of ordinary differential equations and integral equations.	
Unit 3	
Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Relation between Fourier and Laplace transforms.	
Unit 4	
Solution of integral equation by Fourier sine and cosine transforms, Convolution theorem for Fourier transform, Parseval's identity for Fourier transform, Plancherel's theorem, Fourier transform of derivatives, Applications of infinite Fourier transforms to boundary valueproblems, Finite Fourier transform, Inversion formula for finite Fourier transforms.	
Unit 5	

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, Bessel's inequality, The complex form of Fourier series.

Reference Books

- James Ward Brown & Ruel V. Churchill (2011). F*ourier Series and Boundary ValueProblems*. McGraw-Hill Education.
- Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
- Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). Wiley.
- Walter Rudin (2017). *Fourier Analysis on Groups*. Dover Publications.
- A. Zygmund (2002).*Trigonometric Series* (3rd edition). Cambridge University Press.

5.4 DSET4–Tensors and Differential Geometry

Tensors and Differential Geometry	
	6 Credits
Unit1	
Contra variant and covariant vectors, Transformation formulae, Tensor product of two vector spaces, Tensor of type (r, s), Symmetric and skew-symmetric properties, Contraction of tensors, Quotient law, Inner product of vectors.	
Unit2	
Fundamental tensors, Associated covariant and contravariant vectors, Inclination of two vectors and orthogonal vectors, Christoffel symbols, Law of transformation of Christoffel symbols, Covariant derivatives of covariant and contravariant vectors, Covariant differentiation of tensors, Curvature tensor, Ricci tensor, Curvature tensor identities.	
Unit3	
Basic definitions and examples, Arc length, Curvature and the Frenet□Serret formulae, Fundamental existence and uniqueness theorem for curves, Non-unit speed curves.	
Unit4	
Basic definitions and examples, The first fundamental form, Arc length of curves on surfaces, Normal curvature, Geodesic curvature, Gauss and Weingarten formulae, Geodesics, Parallel vector fields along a curve and parallelism.	
Unit5	
The second fundamental form and the Weingarten map; Principal, Gauss and mean curvatures; Isometries of surfaces, Gauss's Theorema Egregium, The fundamental theorem of surfaces, Surfaces of constant Gauss curvature, Exponential map, Gauss lemma, Geodesic coordinates, The Gauss-Bonnet formula and theorem.	

Reference Books

- Christian Bär (2010). *Elementary Differential Geometry*. Cambridge University Press.
- Manfredo P. do Carmo (2016). *Differential Geometry of Curves & Surfaces* (Revisedand updated 2nd edition). Dover Publications.
- Alferd Gray (2018). *Modern Differential Geometry of Curves and Surfaces withMathematica* (4th edition). Chapman & Hall/CRC Press, Taylor & Francis.
- Richard S. Millman & George D. Parkar (1977). *Elements of Differential Geometry*.Prentice-Hall.
- R. S. Mishra (1965). *A Course in Tensors with Applications to Riemannian Geometry*.Pothishala Pvt. Ltd.
- Sebastián Montiel & Antonio Ross (2009). *Curves and Surfaces*. AmericanMathematical Society.

5.5 DSET5–Advanced Mechanics

Advanced Mechanics	
	6 Credits

Unit1

Forces in three dimensions, Reduction to a force and a couple, Equilibrium of a system of particles, Central axis and Wrench, Equation of the central axis, Resultant wrench of two wrenches; Nul points, lines and planes with respect to a system of forces, Conjugate forces and conjugate lines.

Unit2

Moments and products of inertia of some standard bodies, Momental ellipsoid, Principal axes and moments of inertia; Motion of a rigid body with a fixed point, Kinetic energy of a rigid body with a fixed point and angular momentum of a rigid body, Euler's equations of motion for a rigid body with a fixed point, Velocity and acceleration of a moving particle incylindrical and spherical polar coordinates, Motion about a fixed axis, Compound pendulum.

Unit3

Lagrangian and Eulerian approaches, Material and convective derivatives, Velocity of a fluid at a point, Equation of continuity in Cartesian, cylindrical polar and spherical polar coordinates, Cylindrical and spherical symmetry, Boundary surface, Streamlines and pathlines, Steady and unsteady flows, Velocity potential, Rotational and irrotational motion,Vorticity vector and vortex lines.

Unit 4

Euler's equations of motion in Cartesian, cylindrical polar and spherical polar coordinates; Bernoulli's equation, Impulsive motion.

Unit 5

Stream function, Complex potential, Basic singularities: Sources, sinks, doublets, complex potential due to these basic singularities; Image system of a simple source and a simpledoublet with regard to a line and a circle, Milne-Thomson circle theorem.

Reference Books

- A. S. Ramsay (1960). *A Treatise on Hydromechanics, Part-II Hydrodynamics.* G. Bell & Sons.
- F. Chorlton (1967). *A Textbook of Fluid Dynamics*. CBS Publishers.
- Michel Rieutord (2015). *Fluid Dynamics An Introduction.* Springer.
- E. A. Milne (1965). *Vectorial Mechanics*, Methuen & Co.Limited. London.

5.6 DSET6-Advanced Algebra

Advanced Algebra	
	6 Credits
Unit 1	
Group actions, stabilizers, permutation representation associated with a given group action, Applicationsof group actions: Generalized Cayley's theorem, Index theorem. Groups acting on themselves by conjugation, class equation and consequences, Cauchy's theorem (with the proof by class equation), Sylow's theorems (with proofs) and consequences, Simplicity of An for n_5, non-simplicity tests.	
Unit 2	
Divisibility in integral domains, irreducible, primes, unique factorization domains, Principal ideal domain, principal ideal ring, Euclidean domain, relation between Euclidean domain and principal ideal domain. Greatest common divisor(gcd), least common multiple (lcm), expression of gcd, examples of a ring R and a pair of elements $a, b \in R$such that gcd(a, b) does not exist.	
Unit 3	
Polynomial rings, division algorithm and consequences in polynomial rings, results regarding various domains in polynomial rings, Irreducibility in polynomial rings, Eisenstein criterion and uniquefactorization in Z[x]. Ring embedding and quotient field.	
Reference Books	
▸ John B. Fraleigh, A First Course in Abstract Algebra,7th Ed., Pearson,2002. ▸ M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011. ▸ Joseph A. Gallian, Contemporary Abstract Algebra, 4th Ed., 1999. ▸ David S. Dummit and Richard M. Foote, Abstract Algebra, 3rdEd., John Wiley and Sons(Asia) Pvt.Ltd., Singapore, 2004. ▸ J.R.Durbin, Modern Algebra, John Wiley&Sons, New YorkInc., 2000. ▸ D.A.R.Wallace, Groups, Rings and Fields,SpringerVerlagLondonLtd.,1998 ▸ D.S.Malik, John M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra.	

5.7 DSET7–Discrete Mathematics

Discrete Mathematics	
	6 Credits
Unit 1	
Definitions, examples and basic properties of partially ordered sets (poset), Orderisomorphism, Hasse diagrams, Dual of a poset, Duality principle, Maximal and minimalelements, Least upper bound and greatest upper bound, Building new poset, Maps between posets.	
Unit 2	
Lattices as posets, Lattices as algebraic structures, Sublattices, Products andhomomorphisms; Definitions, examples and properties of modular and distributive lattices;Complemented, relatively complemented and sectionally complemented lattices.	
Unit 3	
Boolean algebras, De Morgan's laws, Boolean homomorphism, Representation theorem; Boolean polynomials, Boolean polynomial functions, Disjunctive and conjunctive normal forms, Minimal forms of Boolean polynomials, Quine-McCluskey method, Karnaughdiagrams, Switching circuits and applications.	
Unit 4	
Finite-state machines with outputs, and with no output; Deterministic and nodeterministic finite-state automaton; Turing machines: Definition, examples, and computations.	
Unit 5	
Definition, examples and basic properties of graphs, Königsberg bridge problem; Subgraphs, Pseudo graphs, Complete graphs, Bipartite graphs, Isomorphism of graphs, Paths and circuits, Eulerian circuits, Hamiltonian cycles, Adjacency matrix, Weighted graph, Travelling salesman problem, Shortest path and Dijkstra's algorithm.	
Reference Books	

- B. A. Davey & H. A. Priestley (2002). *Introduction to Lattices and Order* (2nd edition). Cambridge University Press.
- Edgar G. Goodaire & Michael M. Parmenter (2018). *Discrete Mathematics withGraph Theory* (3rd edition). Pearson Education.
- Rudolf Lidl & Günter Pilz (1998). *Applied Abstract Algebra* (2nd edition). Springer.
- Kenneth H. Rosen (2012). *Discrete Mathematics and its Applications***:** *WithCombinatorics and Graph Theory* (7th edition). McGraw-Hill.
- C. L. Liu (1985). *Elements of Discrete Mathematics* (2nd edition). McGraw-Hill.

5.8 DSET8-Point Set Topology

Point Set Topology	
	6 Credits
Unit 1	
Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal Numbers and Cardinal Arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice. Well-Ordered Sets, Hausdorff's Maximal Principle. Ordinal Numbers.	
Unit 2	
Topological spaces, Basis and Subbasis for a topology, subspace Topology, Interior Points, Limit Points, Derived Set, Boundary of a set, Closed Sets, Closure and Interior of a set. Kuratowskii operators, Continuous Functions, Open maps, Closed maps and Homeomorphisms. Product Topology, Quotient Topology, Metric Topology, Baire Category Theorem.	
Unit 3	
Neighbourhood system Connected and Path Connected Spaces, Connected Sets in R, Components and Path Components, Local Connectedness. Compact Spaces with examples, Totally Bounded Spaces, Ascoli-Arzela Theorem, The Lebesgue Number Lemma. Local Compactness.	

Reference Books

- Munkres, J.R.,Topology,A First Course, Prentice Hall of India Pvt. Ltd., NewDelhi, 2000.
- Dugundji, J., Topology, Allynand Bacon,1966.
- Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
- Kelley, J. L., General Topology, Van Nostr and Reinhold Co., New York, 1995.
- Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
- Steen, L., Seebach, J., Counter Examplesin Topology, Holt, Reinhart and Winston, NewYork, 1970.

Abhijit Dasgupta, Set Theory, Birkhäuser.

5.9 DSET9-Special Theory of Relativity

Special Theory of Relativity	
	6 Credits
Unit 1	
Inertial frames, Speed of light and Gallilean relativity, Michelson-Morley experiment, Lorentz-Fitzgerald contraction hypothesis, Relative character of space and time, Postulates of special theory of relativity, Lorentz transformation equations and its geometrical interpretation, Group properties of Lorentz transformations.	
Unit 2	
Composition of parallel velocities, Length contraction, Time dilation, Transformation equations for components of velocity and acceleration of a particle and Lorentz contraction factor.	
Unit 3	
Four dimensional Minkowskian space-time of special relativity, Time-like, light-like and space-like intervals, Null cone, Proper time, World line of a particle, Four vectors and tensors in Minkowiskian space-time.	
Unit 4	
Variation of mass with velocity. Equivalence of mass and energy. Transformation equations for mass momentum and energy. Energy-momentum four vector. Relativistic force and Transformation equations for its components. Relativistic equations of motion of a particle..	
Unit 5	
Transformation equations for the densities of electric charge and current. Transformation equations for electric and magnetic field strengths. The Field of a Uniformly Moving Point charge. Forces and fields near a current carrying wire. Forces between moving charges. The invariance of Maxwell`s equations.	
Reference Books	

1. James L. Anderson (1973). *Principles of Relativity Physics*. Academic Press.
2. Peter Gabriel Bergmann (1976). *Introduction to the Theory of Relativity*. Dover Publications.
3. C. Moller (1972). *The Theory of Relativity* (2nd edition). Oxford University Press.
4. Robert Resnick (2007). *Introduction to Special Relativity*. Wiley.
5. Wolfgang Rindler (1977). *Essential Relativity: Special, General, and Cosmological*. Springer-Verlag.
6. V. A. Ugarov (1979). *Special Theory of Relativity*. Mir Publishers, Moscow.

5.10 DSET10– Number Theory

Number Theory	
	6 Credits
Unit1	
Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linear congruences, complete set of residues, Chinese Remainder theorem, Fermat's Little theorem, Wilson'stheorem.	
Unit 2	
Number theoretic functions, sumand number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues. Some properties of Euler's phi-function.	
Unit 3	
Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadratic reciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation x2+y2=z2, Fermat's Last theorem.	
Reference Books	
▸ David M. Burton, Elementary Number Theory, 6thEd.,TataMcGraw-Hill, Indian reprint, 2007. ▸ Neville Robinns, Beginning Number Theory, 2ndEd., Narosa Publishing House Pvt. Ltd., Delhi, 2007.	

5.11 DSET11–Dissertation on Any Topic of Mathematics

Dissertation on Any Topic of Mathematics	
	6 Credits
Unit 1	
Dissertation have to be prepared on any topic of the Mathematics and submitted to the corresponding supervisor(s) in doc(pdf) format. Finally, it should be presented.	

6. Skill Enhancement Subjects Syllabus

6.1 SECT1–Mathematical Logic

Mathematical Logic	
	4 Credits
Unit1	
First-order languages, Terms of language, Formulas of language, First order theory.	
Unit2	
Structures of first order languages, Truth in a structure, Model of a theory, Embeddings and isomorphism.	
Unit 3	
Syntax of propositional logic, Semantics of propositional logic, Compactness theorem for propositional logic, Proof in propositional logic, Meta theorem in propositional logic, Post tautology theorem.	
Unit 4	
Proof in first-order logic, Meta theorems in first-order logic, Some meta theorem in arithmetic, Consistency and completeness.	
Unit 5	
Completeness theorem, Interpretation in a theory, Extension by definitions, Compactness theorem and applications, Complete theories, Applications in algebra.	
Reference Books	

1. Richard E. Hodel (2013). *An Introduction to Mathematical Logic.* Dover Publications.
2. Yu I. Manin (2010). *A Course in Mathematical Logic for Mathematicians* (2nd edition). Springer.
3. Elliott Mendelson (2015). *Introduction to Mathematical Logic* (6th edition). Chapman & Hall/CRC.
4. Shashi Mohan Srivastava (2013). *A Course on Mathematical Logic* (2nd edition). Springer.

6.2 SECT2–Programming Using C

Programming Using C	
	4 Credits
Unit 1	
An overview of theoretical computers, history of computers, overview of architecture of computer, compiler, assembler, machine language, high level language, object-oriented language, programming language and importance of C programming.	
Unit2	
Constants, Variables and Data type of C-Program: Character set. Constants and variables data types, expression, assignment statements, declaration. Operation and Expressions: Arithmetic operators, relational operators, logical operators.	
Unit3	
Decision Making and Branching: decision making with if statement, if-else statement, Nesting if statement, switch statement, break and continue statement. Control Statements: While statement, do-while statement, for statement.	
Unit 4	
Arrays: One-dimension, two-dimension and multidimensional arrays, declaration of arrays, initialization of one and multi-dimensional arrays.	
Unit 5	
User-defined Functions: Definition of functions, Scope of variables, return values and their types, function declaration, function call by value, Nesting of functions, passing of arrays to functions, Recurrence of function. Introduction to Library functions: stdio.h, math.h, string.h, stdlib.h, time.h etc.	
Unit 6	
Some hands-on examples.	
ReferenceBooks	
▸ B. W. Kernighan and D. M. Ritchi : The C-Programming Language, 2nd Edi.(ANSI Refresher), Prentice Hall, 1977. ▸ E. Balagurnsamy : Programming in ANSI C, Tata McGraw Hill, 2004. ▸ Y. Kanetkar : Let Us C ; BPB Publication, 1999. ▸ C. Xavier : C-Language and Numerical Methods, New Age International. ▸ V. Rajaraman : Computer Oriented Numerical Methods, Prentice Hall of India, 1980.	

6.3 SECT3–GraphTheory

Graph Theory	
	4 Credits
Unit1	
Definition, examples and basic properties of graphs, pseudo graphs, complete graphs, bi-partite graphs, isomorphism of graphs.	
Unit2	
Path and circuits, Eulerian circuits, Eulerian graph, semi-Eulerian graph, theorems, Hamiltonian cycles, theorems Representation of a graph by matrix, the adjacency matrix, incidence matrix, weighted graph.	
Unit 3	
Travelling salesman's problem, shortest path, Tree and their properties, spanning tree, Dijkstra's algorithm, Warshall algorithm.	
Reference Books	
▸ B.A. Davey and H.A. Priestley, Introduction to Lattices and Order, Cambridge UniversityPress, Cambridge, 1990. ▸ Edgar G.Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education(Singapore)P.Ltd., Indian Reprint 2003. ▸ Rudolf Lidl and Gunter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer(SIE), Indian reprint, 2004.	

6.4 SECT4–Operating System:Linux

Operating Systems : Linux	
	4 Credits
Unit1	
Linux – The Operating System: Linux history, Linux features, Linux distributions, Linux's relationship to Unix, Overview of Linux architecture, Installation, Start up scripts, system processes (an overview), Linux Security.	
Unit2	
The Ext2 and Ext3 File systems: General Characteristics of The Ext3 Filesystem, file permissions. User Management: Types of users, the powers of Root, managing users (adding and deleting): using the command line and GUI tools.	
Unit 3	
Resource Management in Linux: file and directory management, system calls for files Process Management, Signals, IPC: Pipes, FIFOs, System V IPC, Message Queues, system calls for processes, Memory Management, library and system calls for memory.	
Reference Books	
▸ Arnold Robbins, Linux Programming by Examples The Fundamentals, 2nd Ed., Pearson Education, 2008. ▸ Cox K, Red Hat Linux Administrator's Guide, PHI, 2009. ▸ R. Stevens, UNIX Net work Programming, 3rd Ed., PHI, 2008. ▸ Sumitabha Das, UNIX Concepts and Applications,4th Ed., TMH, 2009. ▸ Ellen Siever, Stephen Figgins, Robert Love, Arnold Robbins, Linux in a Nutshell, 6th Ed., O'Reilly Media, 2009. ▸ Neil Matthew, Richard Stones, Alan Cox, Beginning Linux Programming, 3rdEd., 2004.	

6.5 SECT5- Programming Using C - Practical

Programming Using C	
	4 Credits

List of practical

1. Calculate the sum 1/1+1/2+1/3+1/4+ ----------+1/N.
2. Enter 100 integers into an array and sort the min an ascending order.
3. Solution of transcendental and algebraic equations.

Note: Data types-simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students.

Syllabus: B.A./B.Sc. with Mathematics as a subject

7. Core Subjects Syllabus: B.A./B.Sc. with Mathematics as a subject

7.1 Core T1A–Calculus and Geometry

Calculus and Geometry	
	6 Credits
Unit 1	
Higher order derivatives, Leibnitz's rule; Indeterminate forms, L' Hospital's rule; Cartesian and Polar subtangent and subnormal; Pedal equation of a curve; Curvature, Radius of Curvature, Centre of Curvature, Circle of Curvature; Concavity, Convexity and Points of inflexions; Envelopes: One and Two parameter family of curves; Rectilinear Asymptotes in Cartesian and Polar Coordinates; Curve tracing of standard curves in Cartesian and Polar Coordinates.	
Unit 2	
Reduction formulae; Parametric equations, Parameterizing a curve; Area under curves in Cartesian and Polar Coordinates; Rectification: Cartesian, Polar and Parametric curves, Intrinsic equations of curves; Volumes and Surfaces of revolution, Improper integrals, Convergency, Beta and Gamma functions and basic properties.	
Unit 3	
Reflection properties of Parabola, Ellipse and Hyperbola; Transformation of rectangular Cartesian coordinates – Translation, Rotation, Orthogonal transformation, General Orthogonal transformation, Invariants; General equation of second degree: Classification of Conics; Polar coordinates: Straight lines, Circles, Conics, Polar equations of tangent, normal and chord of contacts; Pair of Straight lines; Tangents, Normal, Chord of contacts, Pole, Polar.	
Unit 4	

Sphere: General equation, Circle; Cone: General homogeneous second degree equation, Enveloping Cone, Reciprocal Cone, Right circular cone; Cylinder, Right circular cylinder, Enveloping cylinder; Conicoid: Canonical equations of Ellipsoid, Hyperboloid, Paraboloid; Ruled surfaces, Generating lines and their properties, Transformation of coordinates: Invariants; Reduction of general equation of three variables, Concept of Cylindrical and Spherical Polar coordinates.

Reference Books

- G. B. Thomas and R.L.Finney,Calculus, 9th Ed.,Pearson Education, Delhi, 2005.
- M. J. Strauss, G. L. Bradley and K.J.Smith, Calculus, 3rd Ed., Dorling Kindersley(India)P.Ltd.(Pearson Education),Delhi,2007.
- H. Anton, I. Bivens and S.Davis, Calculus, 7th Ed., John Wiley and Sons (Asia) P.Ltd.,Singapore,2002.
- R.Courant and F.John, Introduction to Calculus and Analysis (Volumes I & II), Springer-Verlag, New York, Inc., 1989.
- G. F. Simmons, Differential Equations,Tata McgrawHill.
- T. Apostol, Calculus, Volumes I and II.
- S. Goldberg, Calculus and Mathematical Analysis.
- Marsden, J., and Tromba, Vector Calculus, McGraw Hill.
- Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata(India).
- M. R. Speigel, Schaum's Outline of Vector Analysis

7.2 Core T1B-Algebra

Algebra	
	6 Credits
Unit1	
Complex numbers: Polar and exponential form, n-th roots of unity, De Moivre's theorem for rational indices and its applications, Exponential, Trigonometrical, Logarithmic, Inverse circular and Hyperbolic functions of a complex variable and their properties. Inequalities: AM $\geq$ GM $\geq$ HM, Cauchy-Schwartz inequality, Well-ordering property of positive integers, Division algorithm, GCD and LCM, Divisibility and Euclidean algorithm, Prime numbers, Congruence relation between integers, Fermat's little theorem, Euler's ϕ-function, Statement of Fundamental theorem of Arithmetic.	
Unit 2	
Theory of Equations: Polynomials, Remainder Theorem, Statement of Fundamental theorem of Algebra, Relation between roots and coefficients, Symmetric functions of roots, Transformation of equations, Removal of terms from an equation, Standard cubic, Cardon's method for solving cubic equations, Biquadratic equations: Descartes's and Ferrari's method, Nature of the roots of equation, Descartes rule of sign, Multiple roots, Roll's theorem.	
Unit 3	
Binary composition, Algebraic structure, Definition of Groups, Group properties, Abelian Groups, Simple examples, Order of a group, Order of an element of a group, Subgroups and related theorems, Cosets, Lagrange's theorem.	
Reference Books	
▸ Titu Andreescu and Dorin Andrica, Complex Numbers from A to Z, Birkhauser, 2006. ▸ Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 3rd Ed., Pearson Education(Singapore) P. Ltd., Indian Reprint, 2005.	

- David C. Lay, Linear Algebra and its Applications, 3rd Ed.,Pearson Education Asia, Indian Reprint,2007.
- K. B. Dutta, Matrix and Linear Algebra.
- K.Hoffman, R.Kunze, Linear Algebra.
- W.S.Burnstine and A.W.Panton, Theory of Equations.

7.3 Core T1C-Real Analysis

Real Analysis	
	6 Credits
Unit 1	
Rational numbers, Irrational numbers, Real number system, Order properties, Supremum and infimum, Ordered Completeness property. Real sequences, Bounded sequences, Limit of a sequence, Convergent, Divergent and Oscillatory sequences, Limit theorems, Sandwich theorem, Monotone sequences, Monotone Convergence theorem, Cauchy's general principle of convergence and its applications, Infinite series: Convergence and Divergence, Series of positive terms, Convergency test: Comparison test and its limit forms, D' Alembert's ratio test.	
Unit 2	
Definition of limit of a function, ε-δ approach and sequential approach, Infinite limits and limits at infinity, Continuity of a function, ε-δ approach and sequential approach, Discontinuity and its types, Differentiability at a point and at an interval, Darbaux property, Rolle's theorem, Mean Value theorems (Lagrange and Cauchy), Taylor's theorem – different types of remainders, Infinite Taylor's series, Maclaurin's theorem – finite and infinite form, Infinite series expansion of well-known functions, Relative extrema.	
Unit 3	
Functions of several variables, Limits – Simultaneous and Repeated, Continuity of functions of more than one variable, Directional derivatives, Partial derivatives, Total differentiation, Sufficient condition of total differentiability, Homogeneous functions, Euler's theorem.	
Unit 4	

Double integrals over rectangular and non-rectangular regions, Double integrals in Polar coordinates, Triple integrals over parallelepiped and solid regions. Area by double integral and volume by triple integrals, Cylindrical and Spherical coordinates, Change of variables in double and triple integrals.

Reference Books

- R.G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd Ed., John Wiley and Sons(Asia)Pvt.Ltd.,Singapore,2002.
- Gerald G.Bilodeau, Paul R.Thie, G. E. Keough, An Introduction to Analysis, 2nd Ed., Jones & Bartlett, 2010.
- Brian S. Thomson, Andrew. M. Bruckner and Judith B. Bruckner, Elementary Real Analysis, Prentice Hall, 2001.
- S. K. Berberian, A First Course in Real Analysis, Springer Verlag, NewYork,1994.
- Tom M. Apostol, Mathematical Analysis, Narosa Publishing House
- Courant and John, Introduction to Calculus and Analysis, VolI, Springer
- W. Rudin, Principles of Mathematical Analysis, Tata McGraw-Hill
- Terence Tao, Analysis I, Hindustan Book Agency, 2006
- S. Goldberg, Calculus and Mathematical Analysis.

7.4 Core T1D- Differential Equations and Vector Calculus

Differential Equations and Vector Calculus	
	6 Credits
Unit 1	
First order first degree Ordinary Differential Equations (ODE): Exact equations, conditions of exactness, Integrating factors, Properties, Linear equations, Bernoulli's equations, First order but not first degree: Solvable for p, x and y, Singular solutions, Lagrange's and Clairaut's equations. Higher order linear ODE with constant coefficients: C.F., P.I. and General solutions, Principle of Super position for homogeneous equations, D-operator method for P.I., Method of undetermined coefficients.	
Unit 2	
Lipschitz's condition and Picard's theorem (Statement); Wronskian and its basic properties and applications, Higher order ODE with variable coefficients, Cauchy-Euler type equations, Method of variation of parameters, Solution of a second order ODE when one integral of the CF is known, Simultaneous Linear ODE: Type – I and Type – II, Operator method for type I, Solution of simultaneous ODE of type II, Pfaffian differential equations, Integrability condition, Condition of exactness, Solution of Pfaffian differential equations.	
Unit 3	

Product of three or more vectors, Applications of vectors in Geometry: Vector equation of Straight lines, Angle bisectors, Vector equations of plane, Different forms, Distance of a point from a plane, Shortest distance, Vector equation of a sphere, Applications to Mechanics: Resultant force, Moments, Torque, Lami's theorem and Varignon's theorem.

Unit 4

Vector valued functions with one independent variables, Limits, Continuity, Differentiation of vector functions, Constant vectors, Conditions of constancy of a vector function, Definition of vector field, Directional derivatives, Gradient vector, Maximal and Normal properties of gradient, Divergence and Curl and their properties, Line integrals, Conservative vector field, Surface and Volume integrals.

Reference Books

1. Erwin Kreyszig (2011). *Advanced Engineering Mathematics* (10th edition). J. Wiley & Sons
2. B. Rai & D. P. Choudhury (2006). *Ordinary Differential Equations - An Introduction*. Narosa Publishing House Pvt. Ltd. New Delhi.
3. Shepley L. Ross (2007). *Differential Equations* (3rd edition). Wiley.
4. George F. Simmons (2017). *Differential Equations with Applications and Historical Notes* (3rd edition). CRC Press. Taylor & Francis.
5. Marsden,J.,and Tromba,Vector Calculus, McGraw Hill.
6. Maity, K.C. and Ghosh, R.K. Vector Analysis, New Central Book Agency (P) Ltd. Kolkata(India).
7. M. R. Speigel, Schaum's Outline of Vector Analysis.

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8. Department Specific Electives Subjects Syllabus

8.1 DSET1A-Linear Algebra and Linear Programming Problems

Linear Algebra and Linear Programming Problems	
	6 Credits
Unit 1	
Matrices: Rank, Elementary operations, Elementary matrices, Complex matrices, Hermitian, Skew Hermitian and Unitary matrices, Vector Spaces, Examples of Vector spaces, Subspaces, Linear combination, Linear span, Linearly dependent and independent set of vectors, Properties, Basis and dimension of a vector space, Finite and infinite dimensional vector spaces, Examples, Theorems on basis and dimensions.	
Unit 2	
Row and Column spaces, Rank and Nullity of row and column spaces, Invariance, System of linear equations, its matrix form, Homogeneous and Non-homogeneous systems, Solution space of homogeneous system, Fundamental theorem of Linear algebra, Linear Transformations, Examples, Range and Null spaces, Kernel, Rank and nullity of Linear Transformation, Sylvester's law, Eigen values and Eigen vectors, Properties of Eigen values and Eigen vectors, Matrix Polynomials, Cayley-Hamilton theorem and its applications.	

Unit 3

Introduction of Linear Programming Problems (LPP), Solutions, Basic Solutions (BS), Feasible Solutions (FS), Basic Feasible Solutions (BFS), Degeneracy, Convex Combinations, Convex and Non-convex sets, Examples, Extreme Points, Basic properties, Convex Polyhedron, Convex hull, Fundamental Theorem, Theory of Simplex method, Optimality and unboundedness, Simplex algorithm, Artificial variable techniques, Big-M method and infeasibility.

Unit 4

Duality, Formulation of primal-dual problems, their relationship, Basic properties of primal-dual problems, Fundamental theorem of Duality, Duality and Simplex method, Dual Simplex method, Transportation Problems (TP), Mathematical formulation, Balanced TP, Initial BFS of a TP, North-West corner method, matrix method, VAM for finding IBFS, Algorithm of solving balanced TP, Unbalanced TP.

Reference Books

1. Stephen H. Friedberg, Arnold J. Insel & Lawrence E. Spence (2003). *Linear Algebra* (4thedition). Prentice-Hall of India Pvt. Ltd.
2. Kenneth Hoffman & Ray Kunze (2015). *Linear Algebra* (2nd edition). Prentice-Hall.
3. I. M. Gel'fand (1989). *Lectures on Linear Algebra.* Dover Publications.
4. Mokhtar S. Bazaraa, John J. Jarvis & Hanif D. Sherali (2010). *Linear Programming and Network Flows* (4th edition). John Wiley & Sons.
5. G. Hadley (2002). *Linear Programming*. Narosa Publishing House.
6. Frederick S. Hillier & Gerald J. Lieberman (2015). *Introduction to Operations Research* (10th edition). McGraw-Hill Education.
7. Hamdy A. Taha (2017). *Operations Research*: *An Introduction* (10th edition). Pearson.
8. Paul R. Thie & Gerard E. Keough (2014). *An Introduction to Linear Programming and Game Theory* (3rd edition). Wiley India Pvt. Ltd.

8.2 DSET1A-Statics and Dynamics

Statics and Dynamics	
	6 Credits
Unit 1	
Forces, Various types, Composition and Resolution of forces, Equilibrium of Concurrent forces, Parallel forces, Moment of a force, Couples, Friction, Centre of mass and Centre of gravity, Frictions, Laws of statical friction, Coefficient of friction and angle of friction.	
Unit 2	
Virtual work: Principle of Virtual work, Simple problems, Common Catenary: Suspension of strings, Related problems, Stability of a body: Equilibrium, Stable, Unstable, Test of stability: Energy test.	
Unit 3	
Particle Dynamics: Velocity, Acceleration, Equation of motion, Newton's Laws of motion, Rectilinear motion, Motion in a variable acceleration, Simple Harmonic Motion (SHM), Damped Oscillation, Forced Oscillation, Two dimensional motion – Cartesian and Polar Coordinates, Radial and Cross radial components of velocity and acceleration, Central Force, Equation of motion under central force, Pedal form, Angular momentum, Apse, Apsidal angle, Apsidal distance, Planetary motion, Kepler's Law of motion, Tangential and normal components of velocity and acceleration.	
Unit 4	
Work, Power, Energy, Kinetic and Potential energy, Conservative force, Conservation of Mechanical energy, Impulse of a force, Impulsive force, Principle of conservation of linear momentum, Collision of elastic bodies: Impact, Coefficient of restitution, Newton's empirical law, Related problems.	
Reference Books	

1. S. L. Loney (2006). *An Elementary Treatise on the Dynamics of a Particle and of Rigid Bodies*. Read Books.
2. P. L. Srivatava (1964). *Elementary Dynamics*. Ram Narin Lal, Beni Prasad Publishers Allahabad.
3. J. L. Synge & B. A. Griffith (1949). *Principles of Mechanics*. McGraw-Hill.
4. A. S. Ramsey (2009). *Statics*. Cambridge University Press.
5. A. S. Ramsey (2009). *Dynamics*. Cambridge University Press.
6. R. S. Varma (1962). *A Text Book of Statics*. Pothishala Pvt. Ltd.Loney,

8.3 DSET1B- Number Theory

Number Theory	
	6 Credits
Unit 1	
Linear Diophantine equation, prime counting function, statement of prime number theorem, Goldbach conjecture, linearcongruences, complete set of residues. Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.	
Unit 2	
Number theoretic functions, sum and number of divisors, totally multiplicative functions, definition and properties of the Dirichlet product, the Mobius Inversion formula, the greatest integer function, Euler's phi-function, Euler's theorem, reduced set of residues, some properties of Euler's phi-function.	
Unit 3	
Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots, Euler's criterion, the Legendre symbol and its properties, quadraticreciprocity, quadratic congruences with composite moduli. Public key encryption, RSA encryption and decryption, the equation $x^2 + y^2 = z^2$, Fermat's Last theorem.	
Reference Books	

1. David M. Burton (2007). *Elementary Number Theory* (7th edition). McGraw-Hill.
2. Gareth A. Jones & J. Mary Jones (2005). *Elementary Number Theo*ry. Springer.
3. Neville Robbins (2007). *Beginning Number Theory* (2nd edition). Narosa.

8.4 DSET1B– Probability and Statistics

Probability and Statistics	
	6 Credits
Unit 1	
Sample space, Axiomatic definition of Probability, One dimensional Probability distribution, Random variable, Distribution functions – Discrete and continuous, Properties of distribution functions, Probability mass density, Density functions, Binomial, Poisson, Normal, Exponential, Beta, Gamma, Cauchy distributions, Two dimensional Probability distribution, Distribution functions, Marginal distribution functions, Marginal density functions, Conditional distribution and density functions.	
Unit 2	
One dimensional Expectation, Mean, Variance, Standard deviation, Moments, Central moments, Mean and Variance of Binomial, Poisson and Normal distribution, Expectation in two dimensions, Moments in bivariate distributions, Covariance, Correlation Coefficients and its properties, Conditional Mean and variance, Regression lines, Regression coefficients, Convergence in Probability, Tchebycheff's inequality, Tchebycheff's theorem, Bernoulli's Law, Law of Large numbers, Central limit theorem for equal components (Statement).	
Unit 3	
Sampling Theory, Types of Sampling, Sample Mean, Sample Variance, Sampling distributions, Statistical Inference: Estimation, Point Estimation, Properties: Unbiasedness, Consistency, Efficiency, Sufficiency, Method of Maximum Likelihood, Interval Estimation.	
Reference Books	
1. Robert V. Hogg, JosephW. McKean and Allen T. Craig, Introduction to Mathematical Statistics, Pearson Education, Asia, 2007. 2. Irwin Miller and Marylees Miller, John E. Freund, Mathematical Statistics with Applications, 7th Ed., Pearson Education, Asia, 2006. 3. Sheldon Ross, Introduction to Probability Models, 9th Ed. ,Academic Press, Indian Reprint, 2007.	

9. Skill Enhancement Subjects Syllabus

9.1 SECT1–Basic Numerical Methods

Basic Numerical Methods	
	4 Credits
Unit1	
Approximate numbers and Significant figure, Computational errors: Rounding, Truncation, Absolute, Relative and Percentage errors, Forward and backward differences, different operators, Interpolation, Error in interpolation, Newton's forward, backward interpolations, Newton's divided difference, Lagrange's interpolation.	
Unit2	
Numerical integration: Newton Cote's formula, Trapezoidal, Simpson's one third rule, Geometrical interpretation, Errors. Solution of first order ODE (Initial Value Problems): Euler's method, Picard's method, R. K methods – 2nd and 4th order.	
Unit 3	
Solution of Algebraic and Transcendental equations: Bisection, Fixed Point Iteration method, Geometry, Convergency, Newton Raphson's method, Geometry, Convergency, Method of False Position. Solution of system of linear equations: Gaussian Elimination, Gauss Seidel method, Partial and Complete Pivoting..	
Reference Books	
1. Brian Bradie (2006), *A Friendly Introduction to Numerical Analysis*. Pearson. 2. C. F. Gerald & P. O. Wheatley (2008). *Applied Numerical Analysis* (7th edition), Pearson Education, India. 3. F. B. Hildebrand (2013). *Introduction to Numerical Analysis*: (2nd edition). Dover Publications. 4. M. K. Jain, S. R. K. Iyengar & R. K. Jain (2012). *Numerical Methods for Scientific and Engineering Computation* (6th edition). New Age International Publishers. 5. Robert J. Schilling & Sandra L. Harris (1999). *Applied Numerical Methods for Engineers Using* MATLAB *and C*. Thomson-Brooks/Cole.	

9.2 SECT2–Graph Theory and Mathematical Logic

Graph Theory and Mathematical Logic

4 Credits

Unit 1

Definition of Graphs, Examples, Basic properties, Pseudo graphs, Complete graphs, Bi-partite graphs, Isomorphism of graphs.

Unit 2

Eulerian circuits, Eulerian graphs, Semi-Eulerian graphs, Related theorems, Hamiltonian cycles, Related theorems, Representation of graphs by matrix, the adjacent matrix, Incidence matrix, Weighted graphs.

Unit 3

Travelling salesman problem, Shortest path, Trees and their properties, Spanning tree, Dijkstra's algorithm, Warshall algorithm.

Unit 4

Introduction, Propositions, Truth table, Negation, Conjunction and disjunction, Implications, Biconditional propositions, Converse, Contrapositive and inverse propositions, Precedence of logical operators, Propositional equivalence: Logical equivalence, Predicates and quantifiers: Introduction, Quantifiers, Binding variables and negations..

Reference Books

1. B.A.Davey and H.A.Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, 2nd Edition, Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
4. Richard E. Hodel (2013). *An Introduction to Mathematical Logic.* Dover Publications.
5. Yu I. Manin (2010). *A Course in Mathematical Logic for Mathematicians* (2nd edition). Springer.
6. Elliott Mendelson (2015). *Introduction to Mathematical Logic* (6th edition). Chapman & Hall/CRC.
7. Shashi Mohan Srivastava (2013). *A Course on Mathematical Logic* (2nd edition). Springer.

9.3 SECT3–Programming Using C

Programming Using C	
	4 Credits
Unit1	
Programming in C: C character set, Keywords, Basic data types, Numeric constants and variables, C operators, Expressions, C statements, Assignment statements, I/O statements.	
Unit2	
Control statements: Decision making and looping statements in C, Break, Continue and Goto statements, Simple programs.	
Unit 3	
Subscripted variables, Concept of arrays and array variables in C, Rules for one and two dimensional array, Simple programs.	
Unit 4 Sub programs: Concept of sub programs in C, Purpose of sub programs, Definition of functions and function prototypes, Library functions, Main functions.	
Reference Books	
1. A. R. Venugopal, Rajkumar, and T. Ravishanker, Mastering C++, TMH, 1997. 3. S. B. Lippman and J. Lajoie, C++Primer, 3rd Ed., Addison Wesley, 2000. 4. Bruce Eckel, Thinkingin C++, 2nd Ed., President, Mindview Inc., Prentice Hall. 5. D. Parasons, Object Oriented Programming with C++, BPB Publication. 6. Bjarne Stroustrup, The C++ Programming Language, 3rd Ed., Addison Welsley. 7. E. Balaguruswami, Object Oriented Programming In C++, Tata McGraw Hill Herbert Scildt, C++, The Complete Reference, Tata McGraw Hill.	

9.4 SECT4–Boolean Algebra

Boolean Algebra	
	4 Credits
Unit1	
Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle,maximal and minimal elements, lattices as ordered sets, complete lattices, lattices as algebraic structures,sublattices, products and homomorphisms. Definition, examples and properties of modular and distributivelattices, Boolean algebras..	
Unit2	
Boolean polynomials, minimal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, switching circuits and minimization of switching circuits using Boolean algebra..	
Reference Books	
1. B A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990. 2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory, (2nd Ed.), Pearson Education (Singapore) P.Ltd., Indian Reprint 2003. 3. Rudolf Lidl and Günter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in Mathematics, Springer (SIE), Indian reprint, 2004. 4. J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, 2nd Ed., Addison-Wesley, 2001. 5. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997. 6. J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006	